AMENDMENT OF SOLICITATION/MODIFICATION OF CONTRACT		1. CONTRACT ID CODE		PAGE OF PAGES	
				1	49

2. AMENDMENT/MODIFICATION NO.	3. EFFECTIVE DATE	4. REQUISITION/PURCHASE REQ. NO.	5. PROJECT NO. *(If applicable)*
000002	03/12/2009		

6. ISSUED BY	CODE	GSFC	7. ADMINISTERED BY *(If other than Item 6)*	CODE	GSFC

NASA/Goddard Space Flight Center
Procurement Operations Division
Greenbelt MD 20771

NASA/Goddard Space Flight Center
Procurement Operations Division
Greenbelt MD 20771

8. NAME AND ADDRESS OF CONTRACTOR *(No., street, county, State and ZIP Code)*	(x)	9A. AMENDMENT OF SOLICITATION NO.
		NNG09270323R
	X	9B. DATED *(SEE ITEM 11)*
		03/12/2009
		10A. MODIFICATION OF CONTRACT/ORDER NO.
CODE	FACILITY CODE	10B. DATED *(SEE ITEM 13)*

11. THIS ITEM ONLY APPLIES TO AMENDMENTS OF SOLICITATIONS

X The above numbered solicitation is amended as set forth in Item 14. The hour and date specified for receipt of Offers ☒ is extended. ☐ is not extended.

Offers must acknowledge receipt of this amendment prior to the hour and date specified in the solicitation or as amended, by one of the following methods: (a) By completing items 8 and 15, and returning _____ copies of the amendment; (b) By acknowledging receipt of this amendment on each copy of the offer submitted; or (c) By separate letter or telegram which includes a reference to the solicitation and amendment numbers. FAILURE OF YOUR ACKNOWLEDGEMENT TO BE RECEIVED AT THE PLACE DESIGNATED FOR THE RECEIPT OF OFFERS PRIOR TO THE HOUR AND DATE SPECIFIED MAY RESULT IN REJECTION OF YOUR OFFER. If by virtue of this amendment you desire to change an offer already submitted, such change may be made by telegram or letter, provided each telegram or letter makes reference to the solicitation and this amendment, and is received prior to the opening hour and date specified.

12. ACCOUNTING AND APPROPRIATION DATA *(If required)*

13. THIS ITEM ONLY APPLIES TO MODIFICATION OF CONTRACTS/ORDERS. IT MODIFIES THE CONTRACT/ORDER NO. AS DESCRIBED IN ITEM 14.

CHECK ONE	
	A. THIS CHANGE ORDER IS ISSUED PURSUANT TO: *(Specify authority)* THE CHANGES SET FORTH IN ITEM 14 ARE MADE IN THE CONTRACT ORDER NO. IN ITEM 10A.
	B. THE ABOVE NUMBERED CONTRACT/ORDER IS MODIFIED TO REFLECT THE ADMINISTRATIVE CHANGES *(such as changes in paying office, appropriation date, etc.)* SET FORTH IN ITEM 14, PURSUANT TO THE AUTHORITY OF FAR 43.103(b).
	C. THIS SUPPLEMENTAL AGREEMENT IS ENTERED INTO PURSUANT TO AUTHORITY OF:
	D. OTHER *(Specify type of modification and authority)*

E. IMPORTANT: Contractor ☐ is not. ☐ is required to sign this document and return _____ copies to the issuing office.

14. DESCRIPTION OF AMENDMENT/MODIFICATION *(Organized by UCF section headings, including solicitation/contract subject matter where feasible.)*
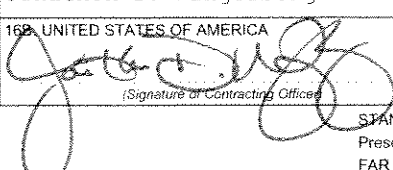
INCO TERMS 2: Destination
The purpose of this amendment is to replace Attachment B Specification
"TIRS-SE-SPEC-0013.pdf" with "TIRS-SE-SPEC-0013A.pdf".

The following sections are updated:
Section 3.1.1, Spec CC-201
Section 3.1.1, Spec CC-202
Section 3.1.2, Spec CC-207.

See attached.

Except as provided herein, all terms and conditions of the document referenced in Item 9A or 10A, as heretofore changed, remains unchanged and in full force and effect.

15A. NAME AND TITLE OF SIGNER *(Type or print)*			16A. NAME AND TITLE OF CONTRACTING OFFICER *(Type or print)*	
			Jonathon D. Wingerberg	
15B. CONTRACTOR/OFFEROR		15C. DATE SIGNED	16B. UNITED STATES OF AMERICA	16C. DATE SIGNED
(Signature of person authorized to sign)			*(Signature of Contracting Officer)*	3/26/09

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Previous edition unusable

STANDARD FORM 30 (REV. 10-83)
Prescribed by GSA
FAR (48 CFR) 53.243

TIRS-SE-SPEC-0013
Revision: A

TIRS Project

Cryocooler Specification

Effective Date: 02/26/2009

Expiration Date: <<Expiration Date: >>

Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and
Space Administration

CM FOREWORD

This document is a TIRS Project controlled document. Changes to this document require prior approval of the TIRS Project CCB Chairperson. Proposed changes shall be submitted to the TIRS Project Configuration Management Office (CMO), along with supportive material justifying the proposed change.

Questions or comments concerning this document should be addressed to:

TIRS Configuration Management Office
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DOCUMENT CHANGE RECORD

REV/ VER LEVEL	DESCRIPTION OF CHANGE	APPROVED BY
Rev-A	Updates per TIRS-CCR-0003	C. Richardson

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

1.1 SCOPE

This specification defines the requirements for the performance, interfaces, environment, and operation of the Thermal Infrared Sensor (TIRS) Cryocooler (Cooler).

1.2 PRECEDENCE

Conflicts arising between the requirements of this specification and the requirements of any document referenced herein will be referred to the GSFC contracting official for resolution.

1.3 APPLICABLE AND REFERENCE DOCUMENTS

1.3.1 Applicable Documents

The TIRS Cryocooler Specification is consistent with, and responsive to, the following applicable documents of the revision and release date shown.

Table 1-1. Applicable Documents

Document Number	Revision/ Release Date	Document Title
		TIRS-Cooler Interface Control Document (ICD)
GSFC-427-03-05		LDCM Environmental Verification Requirements (LEVR)
TIRS-MA-PLAN-0005		TIRS Mission Assurance Implementation Plan (MAIP)
TIRS-SE-PLAN-0010		TIRS Contamination Control Plan

1.3.2 Literature References

For additional clarification, reference is made to documents in the open literature. These documents should be used for clarification and understanding of the requirement. These documents do not constitute additional requirements on the vendor.

Table 1-2. Literature References

Authors	Document Number	Revision/ Release Date	Document Title
	FED-STD-209E		Federal Standard Airborne Particulate Cleanliness Classes in Cleanrooms and Clean Zones
	IEST-STD-CC1246D		Product Cleanliness Levels and Contamination Control Program
	ASTM E595-93		Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment
	MIL-STD-461C		Requirements For The Control Of Electromagnetic Interference Characteristics Of Subsystems And Equipment
	MIL-STD-462	Notice 1	Measurement of Electromagnetic Interference Characteristics of Subsystems and Equipment

2.0 FUNCTIONAL DESCRIPTION

The TIRS Instrument requires a cryocooler with two stages of cooling: the first stage cools a layer of thermal shielding and the second stage cools the Focal Plane Assembly (FPA). The TIRS Cryocooler maintains the instrument focal plane at temperatures required to meet radiometric performance. Cooling of the FPA is accomplished conductively via a shielded Thermal Strap Assembly (TSA) that also provides contamination control for the cold surfaces. The two identified models of cryocooler are the Engineering Model (EM) and a Flight Model (FM).
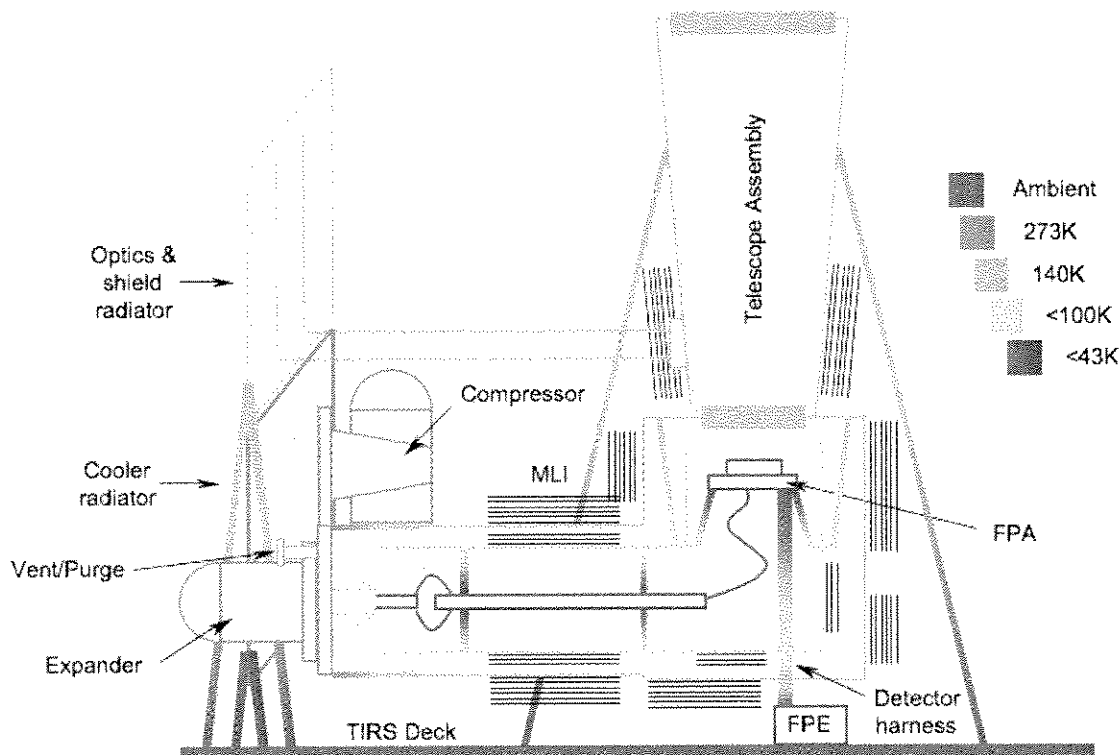
Figure 2-1. Conceptual Location of the Cryocooler on the TIRS Instrument
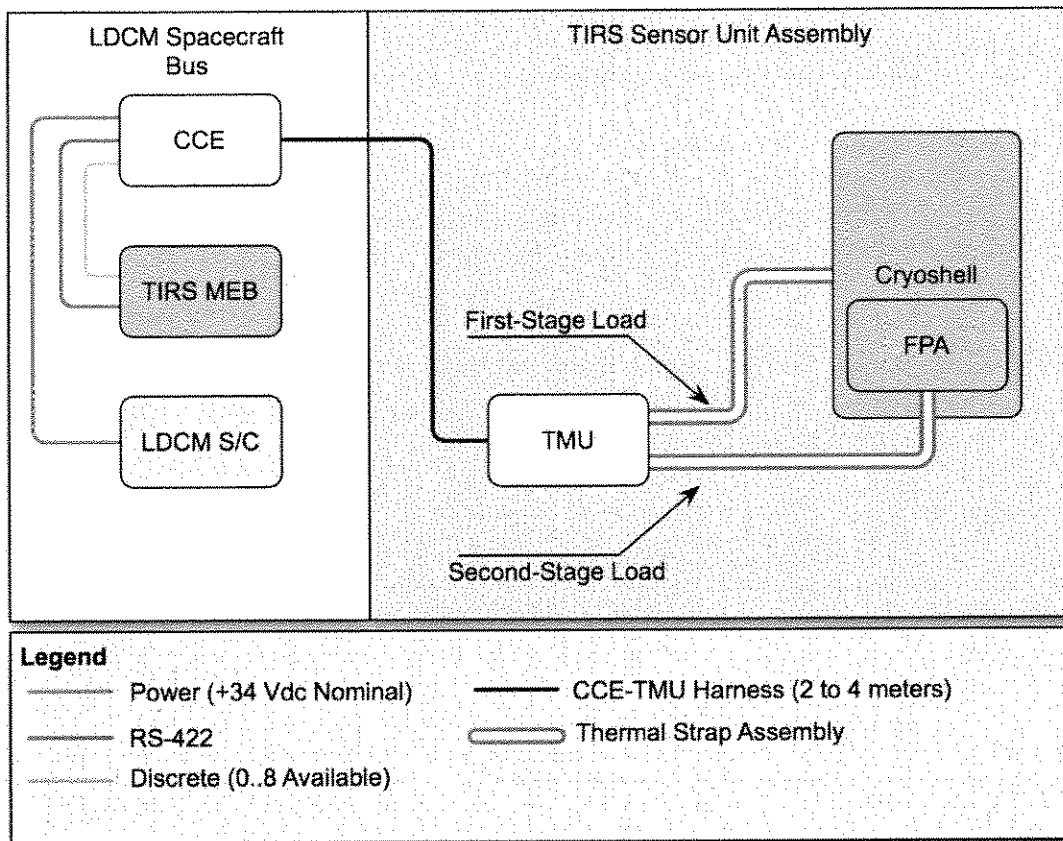
Figure 2-2. TIRS Cooler Block Diagram

2.1 DEFINITION OF TERMS

The paragraphs below describe a general set of definitions for items used throughout this document.

Cooler Control Electronics (CCE): The CCE converts, conditions, switches, and distributes incoming +34 Vdc (nominal) spacecraft (SC) power, and furnishes it in the correct form to drive the TMU of the Cooler. The CCE also provides closed-loop control of various compressor and cold-head functions, monitors the status of key performance and safety parameters, and communicates with the TIRS Main Electronics Box (MEB) via an RS-422 connection. Generally these control functions will involve analog and digital circuitry, and supporting software and/or firmware.

End-Of-Life Cooling Capacity: The End-of-Life (EOL) Cooling Capacity is defined as the cooling capacity at the coldload interfaces at the predicted EOL Condition with all host thermal interfaces at their maximum Flight Allowable-Operating temperatures.

End-Of-Life Operating Point: The End-of-Life (EOL) Operating Point (EOP) is defined as the Cooler at equilibrium with all host thermal interfaces and with the cryogenic loads applied and all host thermal interfaces at their maximum Flight Allowable-Operating temperatures.

End-Of-Life Operating Point Input Power: EOP Input Power is defined as the input power to the Cooler Control Electronics at nominal bus voltage with all host thermal interfaces at their maximum Flight Allowable-Operating temperatures, with the Cooler in its Predicted EOL Condition, and with the cold-head loads corresponding to the EOL Operating Point.

Engineering Model (EM): The EM Cryocooler shall consist of a single TMU, form, fit and function identical to the flight unit, and its associated control electronics. The EM electronics need not be packaged for flight, but shall include all the functionality of the flight CCE.

First-Stage Load Interface: The thermo-mechanical attach point on the first ("warm") stage of the coldhead.

Flight Model (FM): The FM Cryocooler consists of a single flight compressor and expander/coldhead assembly, referred to as the Thermo-Mechanical Unit (TMU), a single remote flight Cooler Control Electronics (CCE), and a flight wire harness to connect the CCE to the TMU.

Margin: margin is defined as follows:

Margin = Allocation − Current Best Estimate (CBE)

$$\text{Percentage Margin} = \frac{\text{Margin}}{\text{Allocation}} \times 100$$

Note: CBE includes uncertainties.

Second-Stage Load Interface: The thermo-mechanical attach point on the second ("cold") stage of the coldhead.

Thermal Strap Assembly (TSA): The assembly of a thermal strap for conductive cooling of the Focal Plane Assembly (FPA) and two layers of coaxial thermal shields. The inner thermal shield is actively cooled to its thermally balanced temperature and the outer shield is conductively cooled by the telescope radiator to under 160 K. The TSA is also intended for contamination control for the cold surfaces.

Thermo-Mechanical Unit (TMU): The Thermo-Mechanical Unit consists of two elements of the Cooler; the compressor and the expander or coldhead. The compressor provides a compressed gas pressure wave to the cold head assembly, integrally or through a transfer line. The compressor and expander are structurally mounted at their heat rejection interface.

2.2 COMMON UNITS OF MEASURE

Table 2-1. Common Units of Measure

Quantity	Unit	
	Name	Symbol
Data Rate	Kilobits Per Second	kbps
Electrical Potential	Volt	V
Energy	Electron Volt	eV
Force	Newtons	N
Force of Gravity	G	G
Frequency	Hertz	Hz
Length	Meter	m
Mass	Kilogram	kg
Power	Watts	W
Resistance	Ohms	Ω
Temperature	Kelvin	K
Temperature	Celsius	C
Thermal Conductance	Watts/Kelvin	W/K
Volts Direct Current	Volts DC	Vdc

Note that for this document, 1 kilobit is defined as 1024 bits.

2.3 ORIENTATION

2.3.1 TMU Orientation & Coordinates

The TMU will be mounted within the given volume allocation on the cryocooler radiator and will share the TIRS coordinate system as shown in Figure 2-3 and Figure 2-4.
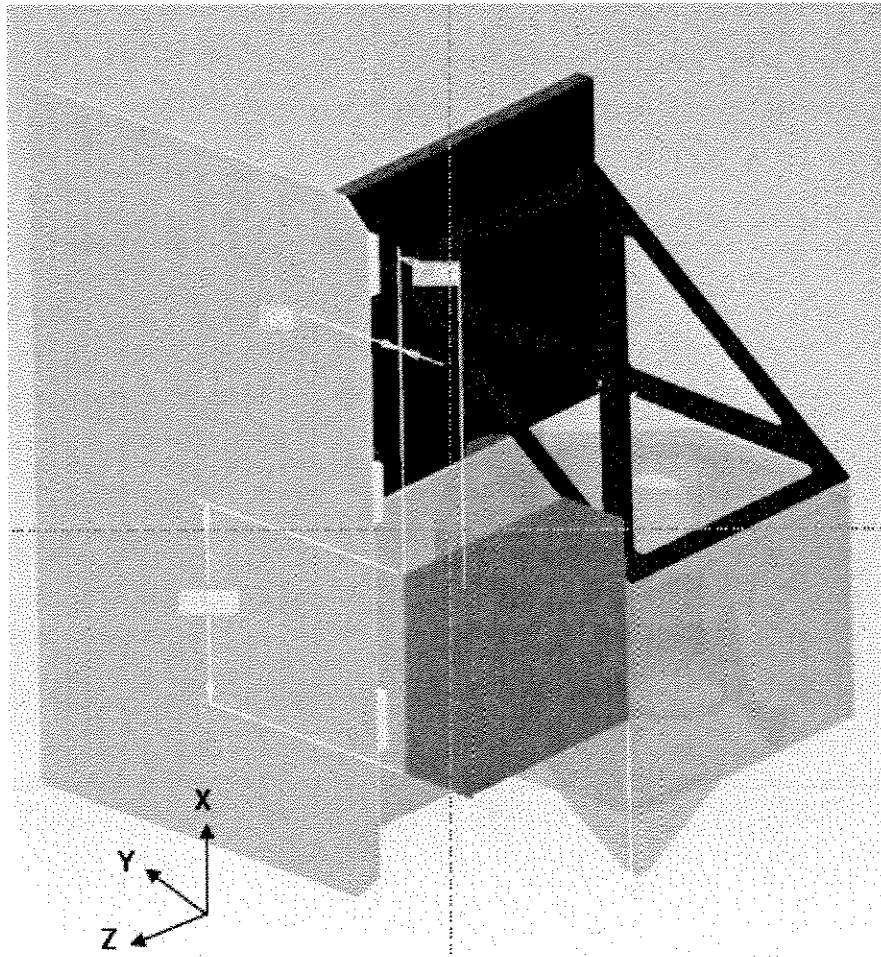
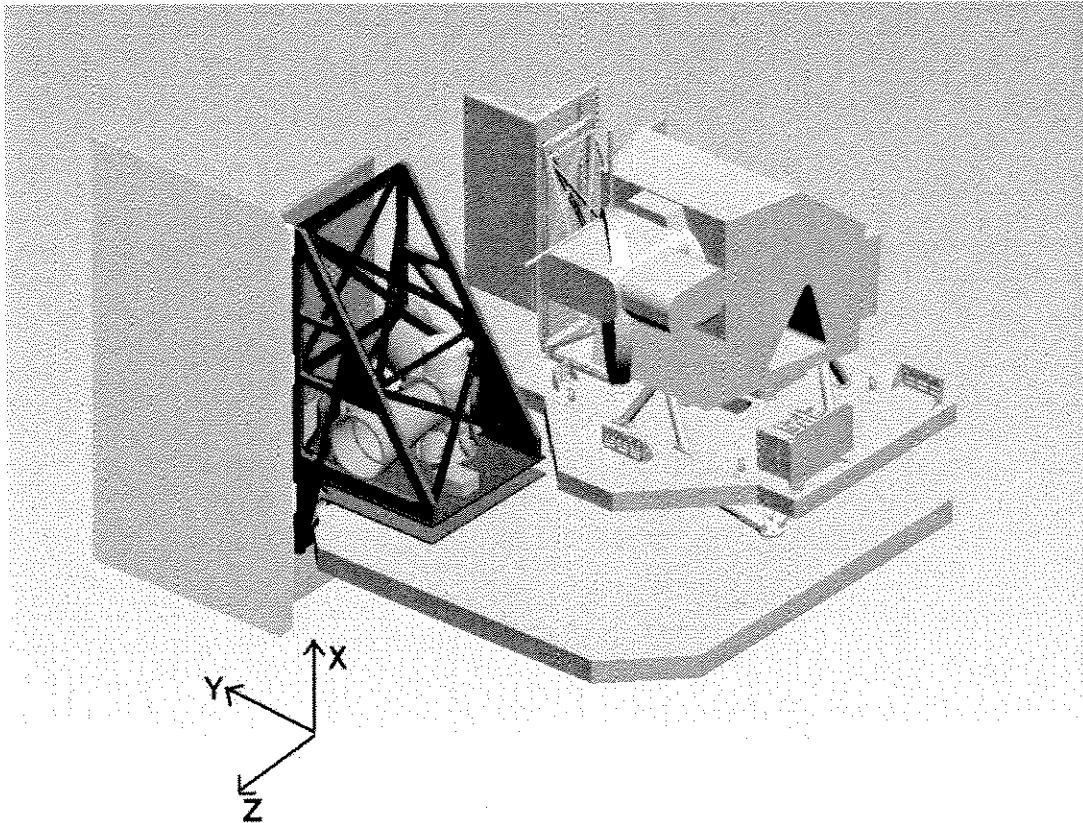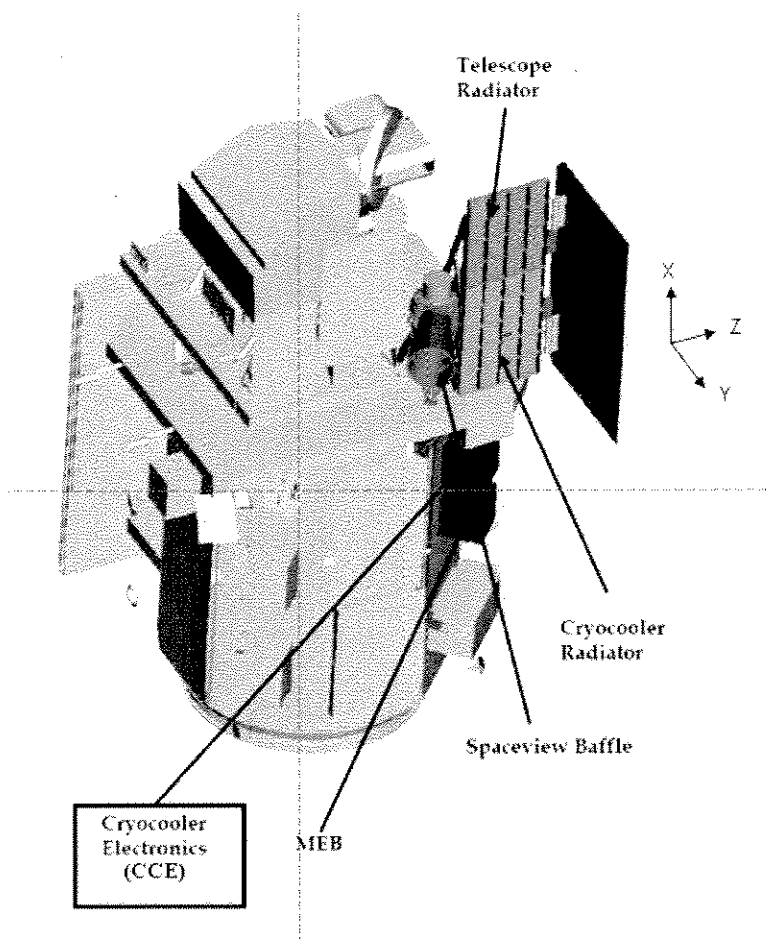**Figure 2-3. TMU Within LDCM Coordinate System**

Figure 2-4. TIRS Sensor Unit Coordinates Reference

2.3.2 CCE Orientation & Coordinates

The CCE will be located on the spacecraft bus and share the TIRS coordinate system as shown in Figure 2-5.

Figure 2-5. CCE Location and Orientation on LDCM

3.0 REQUIREMENTS

3.1 PERFORMANCE REQUIREMENTS

CC-195   The Cooler shall meet all performance requirements in this specification in 0 G.

CC-196   The Cooler shall meet all performance requirements during ground testing in 1 G with its cold-finger axis/axes at 90 degrees to the vertical.

CC-197   The Cooler shall be capable of demonstrating the health of its principal functions and interfaces in a test at ambient temperature and pressure and lasting less than 30 minutes. Note: The System Functional Test (SFT) will be used as a benchmark health check-in test at every level of assembly/integration.

CC-198   The Cooler shall have an overall reliability of at least 96% at the end of its specified operating lifetime.

CC-199   The Cooler shall meet its performance requirements with a compressor-to-expander separation (transfer line length) of 0.30 meters.

3.1.1 Cooling Performance

CC-201   The Cooler shall provide 2 W of cooling power at its Second-Stage Load interface at an operating set-point temperature under 40 K given the Power Performance specified in Section 3.1.2 of this specification.

CC-202   The Cooler shall provide 3 W of cooling power at its First-Stage Load interface at an operating temperature under 100 K given the Power Performance specified in Section 3.1.2 of this Specification.

CC-203   The Cooler Second-Stage set-point temperature shall be capable of being set to any temperature in the range from 30 K to 50 K to an accuracy of ±100 mK.

CC-204   The Cooler shall be capable of limiting the variation of the Second-Stage Load interface temperature to less than 10 mK peak-to-peak over a 34 minute period.

3.1.2 Power Performance

CC-207   The Cooler shall meet the Cooling Performance specified in Section 3.1.1 of this Specification, at End Of Life (EOL) and a heat rejection temperature of 273K, while drawing less than 225 W of spacecraft bus power.

CC-208   The Cooler total transient in-rush current limits shall not exceed 250% of the Maximum Steady State (MSS) current.

CC-209   The duration of the Cooler total transient in-rush current shall be less than 50 milliseconds as shown in Figure 3-1.
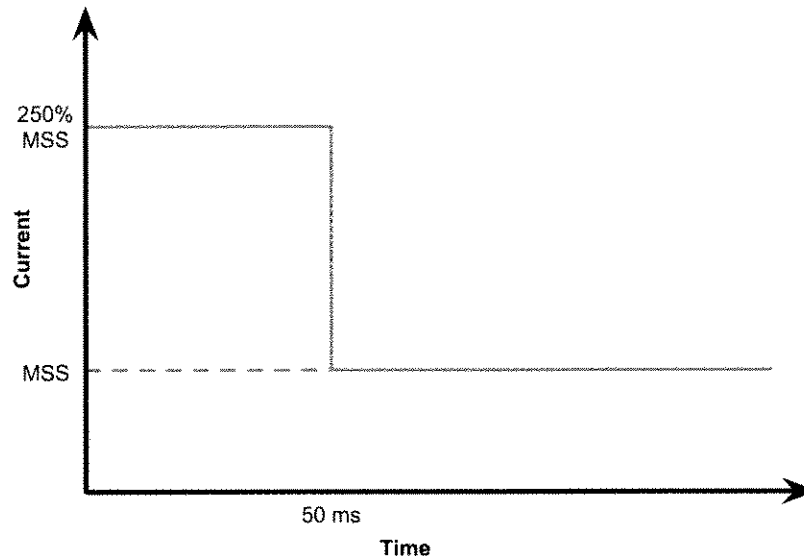
Figure 3-1. Cooler Turn-on Transient Limits

CC-212   During all normal operating modes, component common mode voltage shall never exceed 100 mV peak-to-peak (50 mV goal) from 30 Hz to 50 MHz.

CC-213   Measurements to verify compliance with the common mode noise requirement shall be made between the current probe around +32 Vdc and between return and ground.

CC-214   The Cooler shall be unharmed in the event that the spacecraft removes power input without prior notice.

CC-215   The Cooler shall continue to operate if both sides of the spacecraft become powered simultaneously.

CC-216   The Cooler shall power up in a known safe state, even after unannounced power removal.

3.1.3   Monitoring Performance

CC-218   The Cooler instrumentation shall contain temperature sensors to verify the thermal model, and assess the health and performance of the Cooler over its lifetime.

CC-219   The Cooler First-Stage Load interface temperature sensors and their readout electronics shall be capable of measuring the interface temperature in the range from 60 K to 323 K.

CC-220   In the temperature range 60 K to 323 K, the Cooler First-Stage Load interface temperature sensors and their readout electronics shall be capable of a resolution of ±1 K, with an accuracy of ±1 K, over the mission duration.

CC-221   The Cooler Second-Stage Load interface temperature sensors and their readout
          electronics shall be capable of measuring the interface temperature in the range
          from 30 K to 323 K.

CC-222   In the temperature range 61 K to 323 K, the Cooler Second-Stage Load interface
          temperature sensors and their readout electronics shall be capable of a resolution
          of ±1 K, with an accuracy of ±1 K, over the mission duration.

CC-223   In the temperature range 30 K to 60 K, the cooler Second-Stage Load interface
          temperature sensors and their readout electronics shall be capable of a resolution
          of ±1 mK, with an accuracy of ±1 mK, over the mission duration.

3.1.4 Lifetime Performance

CC-225   The Cooler shall have an operating life no less than 35,000 hours (~4 years)
          including both in-space operation and ground-test operation.

CC-226   The Cooler shall have a non-operational ground storage state that does not require
          intervention for at least 30 days.

CC-227   The Cooler shall be capable of operating for no less than 500 start/stop cycles and
          200 cryogenic cooling cycles over its operating life. Note: A cryogenic cooling
          cycle consists of a cooldown from ambient to cryogenic temperatures and a
          warm-up from cryogenic to ambient temperatures.

CC-228   The Cooler shall have a working-fluid leak rate of less than $1.0E-9$ std cc/s, as
          measured by a calibrated helium mass spectrometer, when inside of a vacuum
          chamber and the components are pressurized.

3.2 INTERFACE REQUIREMENTS

The detailed interfaces between the Cooler and TIRS and between the Cooler and the SC will be
defined in the TIRS-Cooler ICD

3.2.1 Thermal Interface

CC-232   The cold-finger Second-Stage Load interface shall be configured with a bolted-
          joint conductive cold-load interface suitable for conducting its cryogenic load to
          the Cooler with a thermal conductance of > 4 W/K at 40 K across the bolted joint.

CC-233   The cold-finger First-Stage Load interface shall be configured with bolted-joint
          conductive cold-load interface suitable for conducting its cryogenic load to the
          Cooler with a thermal conductance of >6 W/K at 100 K across the bolted joint.

CC-234   The Compressor and Expander conductive heat rejection interfaces shall be
          defined in the TIRS-Cooler ICD.

CC-235   The expander coldfinger(s) shall be mechanically integrable with the multilayer
          coaxial TSA in a manner that allows for the contamination closeout of the outer
          TSA layer while meeting all other requirements of this specification.

3.2.2 Mechanical Interface

CC-237   Interface disturbances generated by the TMU, with active vibration cancellation turned on, shall not exceed 0.1N in any axis for the first three harmonics and 0.2N for higher harmonics.

CC-238   The Cooler shall employ active electronic noise cancellation.

CC-239   The Cooler compressor fundamental drive frequency shall, by software command, be capable of being changed from the baseline drive frequency by at least +/- 7%.

3.2.3 Electrical Power Interface

CC-241   The Cooler shall receive 2 (1 Primary, 1 Redundant) unregulated +34 Vdc bus operational power connections from the SC.

CC-242   The Cooler shall be compatible with an input voltage range from +22 Vdc to +36 Vdc with a nominal of +34 Vdc.

CC-243   The Cooler shall be undamaged with the application of power between 0 Vdc and +40 Vdc.

CC-244   The return lines for power and status shall be separate

CC-245   The Cooler shall use suppression devices at the source of the inductive transients, such as diodes across all relay coils or other energy sources that could induce transients on the power lines during turn-off.

CC-246   The Cooler shall be protected from over or under voltage from the SC.

CC-247   The Cooler shall be compatible with a noise and ripple input less than 1.0 Volts peak-to-peak over the frequency range of 1 Hz to 10 MHz; and less than 0.5 Volts peak-to-peak for frequencies over 10 MHz, at the input to the Cooler.

CC-248   During all normal operating modes, component common mode voltage shall never exceed 100 mV peak-to-peak (50 mV goal) from 30 Hz to 50 MHz.

CC-249   Measurements to verify compliance with the common mode noise requirement shall be made between the current probe around +32 Vdc and between return and ground.

CC-250   The Cooler power connectors shall be male on the Cooler side to protect from accidental short-circuit.

CC-251   Cooler grounding shall be consistent with the TIRS-Cooler ICD.

CC-252   The Cooler primary power leads and returns shall be isolated from signal and chassis ground by a DC resistance greater than 1 MΩ when measured with test equipment supplying potential up to +40 Vdc.

CC-253   The Cooler DC/DC isolation converter in the CCE shall connect its secondary power return lines to the CCE's chassis

CC-254   The Cooler secondary power returns shall be isolated from primary power returns by a DC resistance greater than 1 MΩ.

CC-255   DC/DC isolation converters providing power to external equipment such as remote sensors shall provide that power on separate dedicated power outputs, which will be grounded to chassis only at one end, either at the converter or the load, but not at both ends.

CC-256   Each discrete heater shall be isolated from the local signal reference plane.

CC-257   Each discrete heater shall be referenced to the signal ground in the electronics box containing its respective drive circuitry.

CC-258   Each discrete telemetry point, whether analog or bi-level, shall be isolated from the local signal reference plane.

CC-259   Each discrete telemetry point, whether analog or bi-level, shall be connected differentially to its respective sense circuitry.

CC-260   The body of each chassis connector shall be electrically connected to the chassis with a DC resistance less than or equal to 10 mΩ.

3.2.4 Data Interface

CC-262   The Cooler shall interface with TIRS for command and telemetry through an RS-422 connection in accordance with the TIRS-Cooler ICD.

CC-263   Telemetry rate and latency for data accessed through the RS-422 link shall be defined and documented in the TIRS-Cooler ICD.

CC-264   The Cooler shall be configured by command from TIRS.

CC-265   The Cooler vendor shall identify a number, not to exceed eight (8), discrete pulse commands that will be provided.

CC-266   The Cooler shall have independent data drivers and receivers for data interfaces.

3.2.5 Command Interface

CC-268   The Cooler shall receive commands from the TIRS MEB.

CC-269   The Cooler shall require a command frequency of 4 Hz or less.

CC-270   The Cooler shall have no commands that result in a command lockout.

CC-271   The Cooler shall have no single command that could cause the loss of the Cooler assuming no previously failed components.

CC-272   The Cooler shall have no single command that could cause the loss of TIRS assuming no previously failed components.

CC-273   The Cooler shall reject invalid commands.

CC-274   The Cooler shall have no commands that depend on the initial state, such as a toggle command.

CC-275   The Cooler shall be capable of verifying command execution via telemetry.

3.2.6   Telemetry Interface

CC-277   The Cooler telemetry production shall not exceed 2 kbps orbital average during nominal operations.

CC-278   The Cooler telemetry data packet structure shall be as defined in the TIRS-Cooler ICD.

CC-279   The Cooler shall report within its telemetry parameters the status of the last command executed.

3.2.7   Flight Software & Firmware

CC-281   All Cooler software and/or firmware shall be implemented with an internal version identifier (embedded in the executable) that can be included in telemetry.

CC-282   The Cooler software and/or firmware shall be designed so that revisions or parameter uploads can be installed and verified in-flight.

CC-283   The Cooler shall carry a copy of the baseline Cooler parameters required to provide normal Cooler operation (such as startup, vibration and temperature control, monitoring, etc.), which can, upon power-up, be utilized as a default.

CC-284   The Cooler software and/or firmware shall be capable of receiving updates over multiple ground contacts.

3.2.8   Test Interface

CC-286   Test points and Integration and Test (I&T) interfaces shall be accessible, clearly marked, and designated when the Cooler is mounted to TIRS, and when the TIRS is installed on the LDCM Spacecraft. Note: Cooler test points and I&T interface accessibility will be detailed in the TIRS-Cooler ICD.

CC-287   All connectors on test cables that interface with connectors on the flight hardware shall be of flight quality.

CC-288   Test points shall not be used for acceptance or verification of the Cooler performance requirements. Test points for use at the TIRS/LDCM level integration and test will be used for trouble shooting only.

CC-289   Test connectors shall utilize the side of a male/female pair that offers the better protection against accidental short-circuits

CC-290   Test points shall be designed and implemented in accordance with all applicable flight standards and component ratings.

CC-291   Test connectors shall not be used to provide power to internal Cooler circuitry with the exception of components that are used exclusively for test and are completely isolated from flight circuitry.

CC-292   Test connectors shall comply with grounding requirements as defined in the TIRS-Cooler ICD.

CC-293   All test points shall incorporate short-circuit protection.

CC-294   Test point interface circuit and equipment failures shall not propagate failures into TIRS.

CC-295   Captive Electromagnetic Interference (EMI) connector covers shall be installed whenever the test connector is not in use.

3.3   ENVIRONMENT REQUIREMENTS

CC-297   The Cooler shall be designed to be compliant with the LDCM Environmental Verification Requirements (LEVR).

3.3.1   Thermal Environment

CC-299   The temperature at the CCE mounting interface shall be compliant with the TIRS-Cooler ICD.

CC-300   The total heat transfer of the CCE shall be less than the value specified in the TIRS-Cooler ICD.

CC-301   The CCE shall radiate as defined in the TIRS-Cooler ICD.

CC-302   The CCE minimum power on temperature shall be documented in TIRS-Cooler ICD.

CC-303   The temperature range of the CCE while unpowered shall be - 35 C to +55 C.

CC-304   The CCE shall be capable of being turned on at the CCE cold survival temperature.

3.3.2   Electromagnetic Compatibility (EMC) Environment

The EMC specifications given in this section are based on the test requirements of MIL-STD-461C and MIL-STD-462 as amended by Notice 1, and IEEE-63. All references in this document to MIL-STD-462 assume reference to Notice 1.

3.3.2.1   Conducted Emissions

CC-308   Conducted Emissions (CE) on Cooler power, and power-return leads shall be limited to the levels specified in Figure 3-2

LDCM CE 01/03 Limit

Freq (kHz)	Level (dBuA)
0.03	120
0.3	120
20	50
2000	20
50000	20

Spacecraft subsystems, components, and instruments
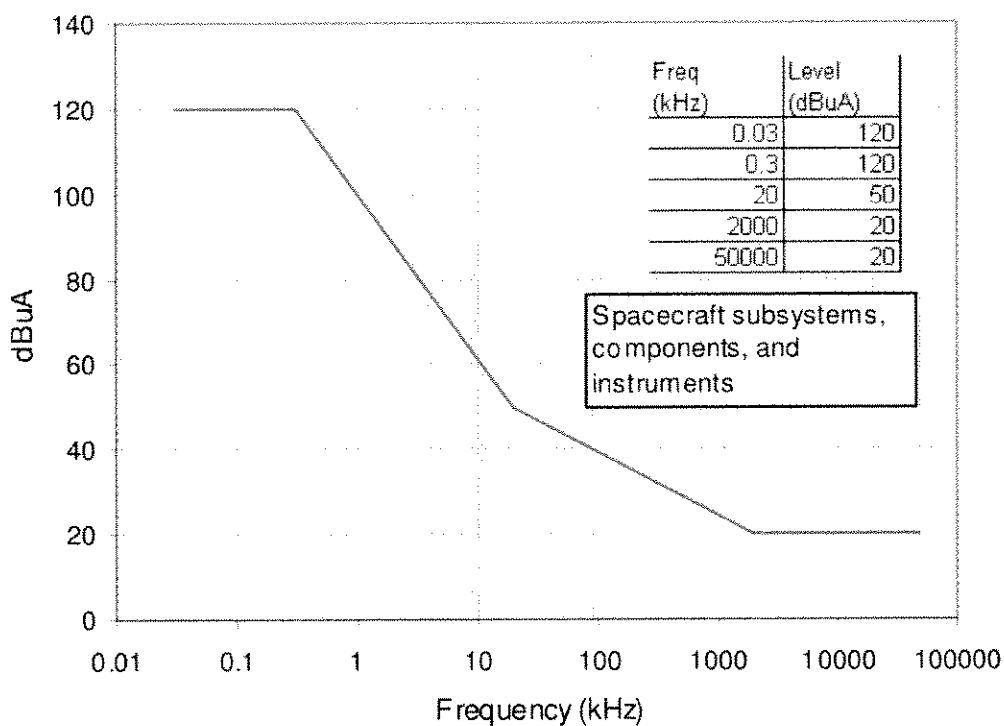
Figure 3-2. Conducted Emissions Limits on Power Lines

CC-311   The Cooler CE Common Mode Noise (CMN) shall be limited to the levels shown in Figure 3-3.

LDCM Common Mode Noise (CMN) Limit

Freq (MHz)	dBuA
0.00003	50
0.02	50
2	20
50	20
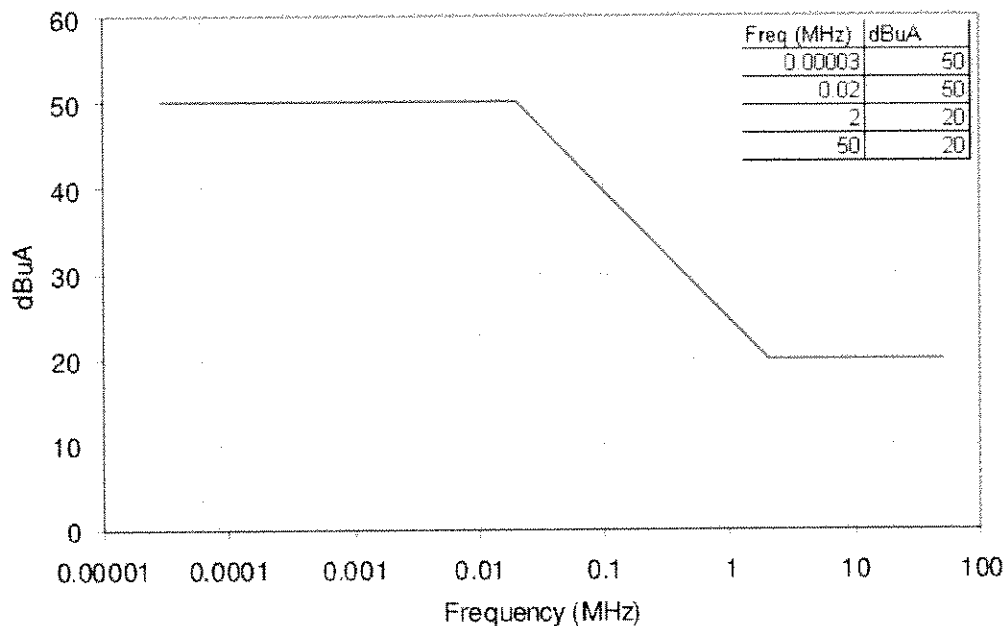
Figure 3-3. Common Mode Conducted Emissions Limits on Power Lines

3.3.2.2 Radiated Emissions

CC-315   Unintentional radiated narrowband electric field levels produced by the Cooler shall be limited to the levels specified in Figure 3-4.

LDCM RE02 Limit
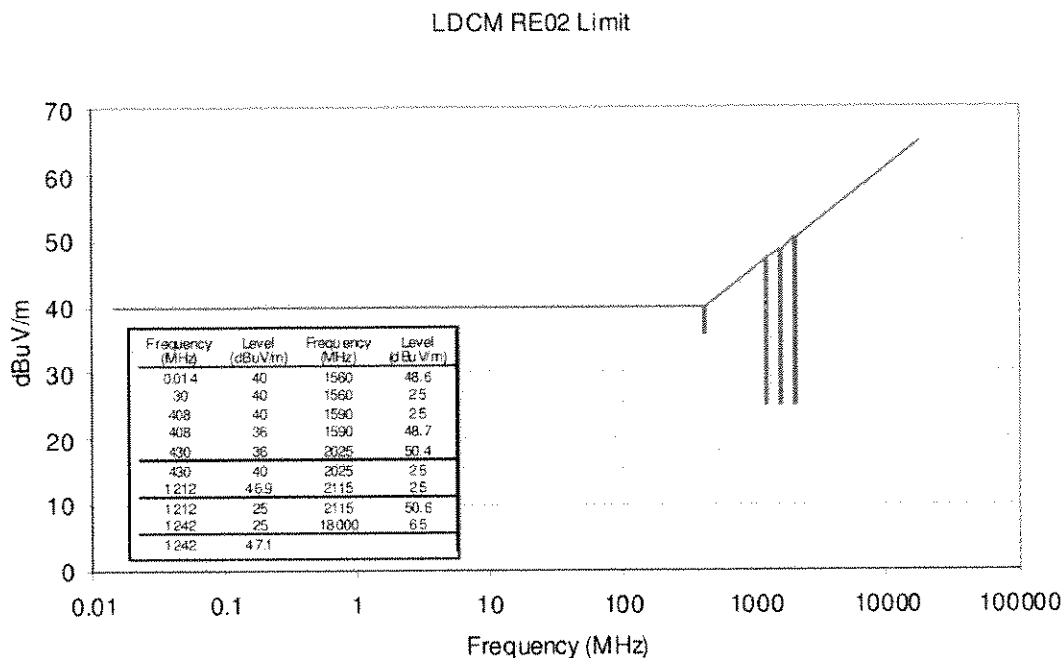
Figure 3-4. Unintentional Radiated Narrowband Electric Field Limits

3.3.2.3 Conducted Susceptibility

CC-319 The Cooler Conducted Susceptibility levels, under the conditions of the Conducted Susceptibility (CS) test CS01, shall not exceed those shown in Figure 3-5.

LDCM CS01 Limit
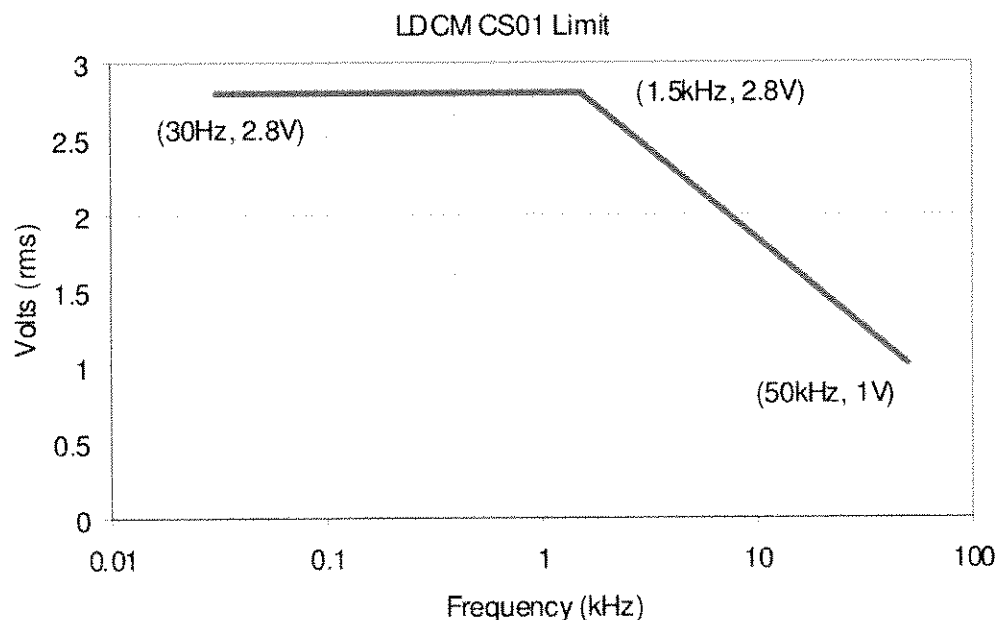
Figure 3-5. Powerline Conducted Susceptibility Limits

CC-322   Cooler Conducted Susceptibility levels, under the conditions of the Conducted
         Suseptibility (CS) test CS02, shall not exceed those shown in Figure 3-6.

Figure 3-6. Power Line Conducted Susceptibility

CC-325   The Cooler shall be able to survive the CS06 Conducted Susceptibility test with
         the transient applied defined in Figure 3-7 as per the CS06 testing environment.
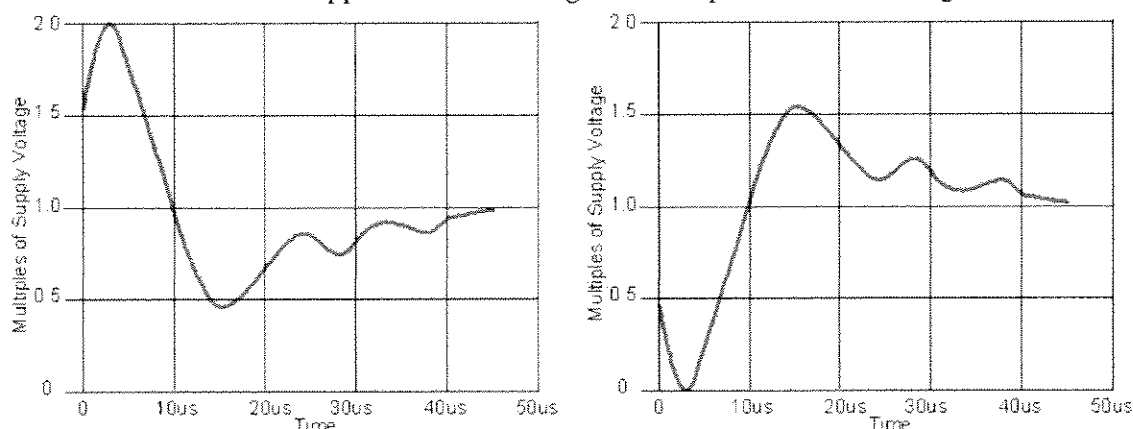
Figure 3-7. Transient Conducted Susceptibility on Powerlines

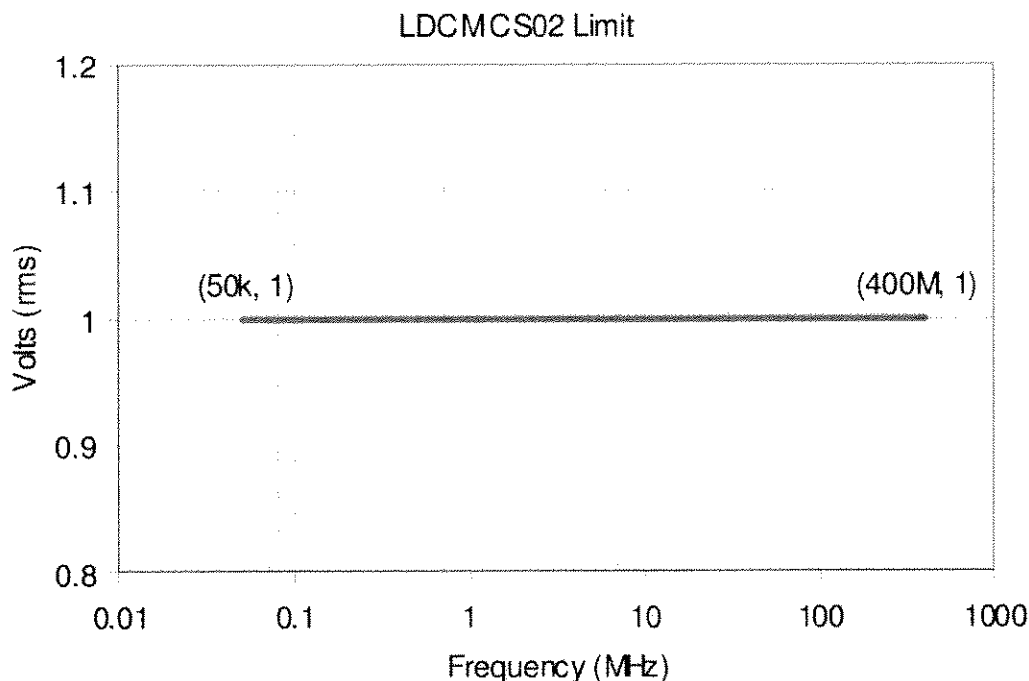### 3.3.2.4 Radiated Susceptibility Requirements

CC-329   The Cooler shall survive in a powered state when exposed to external
         electromagnetic signals in accordance with the requirements and test methods of
         the Radiated Susceptibility (RS) test RS03, using the appropriate modulation of
         the applied susceptibility signal and the test levels as defined in Table 3-1.

Table 3-1. Radiated Susceptibility Limits for Operations at VAFB

Atlas V at Space Launch Complex 3E							
Emission Source	**Start (GHz)**	**End (GHz)**	**Pad RF Level (V/m)**	**Transport RF Level (V/m)**	**6 dB Margin Added (V/m) [1]**	**Comments**	
Range Sources							
Baseline Level	14 kHz	18	10	10	20	Generic Level	
ARSR-4	1.215	1.4	18.2	33.1	67		
NEXRAD	2.89	2.89	32.3	33.2	67		
Range Radars	5.4	5.9	20	20	40 [2]		
PULSTAR	9.245	9.392	33.1	40.3	81		
Atlas V 4M Fairing Configuration - Standard LV Adapter (C22)							
Vehicle S-Band	2.211	2.211	17.4	---	35	Assumes use of C22	
Vehicle C-Band	5.765	5.765	65.8	---	132	Assumes use of C22	
Spacecraft Open Air, Near Field Emissions							
S-Band	2.2	2.29	12	0	12	Assumes use of 2 Omni Antennas	
X-Band	8.025	8.4	17	0	23	Accounts for Earth Coverage Transmitter	

[1] 6 dB Margin added to the higher level of the two previous columns
[2] Assumes standard PRD is filled with the range

CC-424   The Cooler shall meet all requirements during a 22 second exposure to the radiated emissions defined in the on-orbit operational environment contained in Figure 3-8.
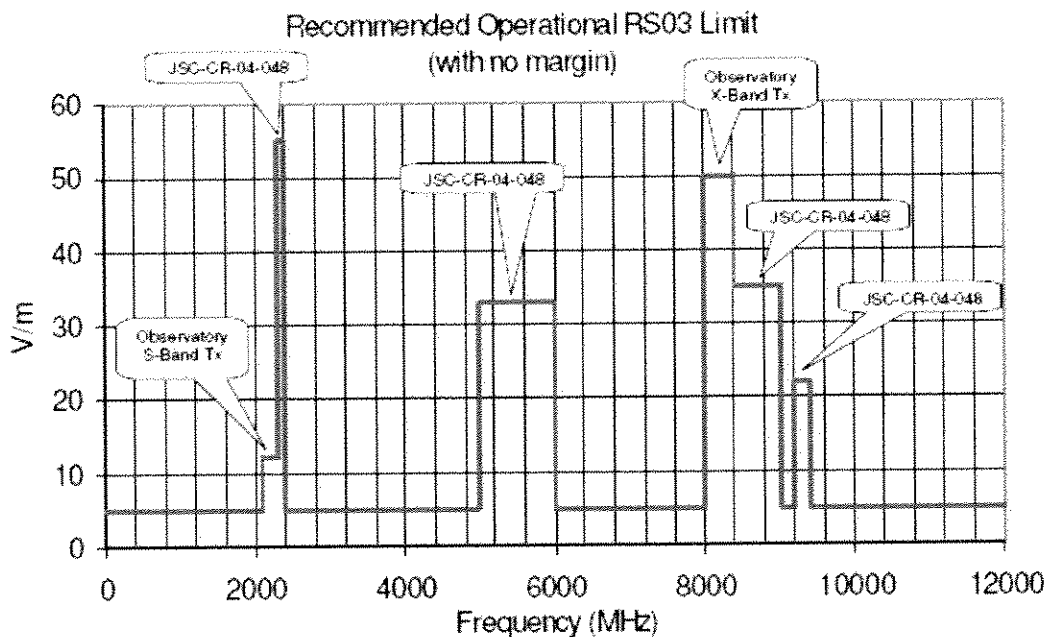
Figure 3-8. On-Orbit Operational Radiated Susceptibility Environment

3.3.3 Space Radiation Environment

CC-428   The Cooler shall meet its lifetime requirement in the radiation environment specified in Figure 3-9 to Figure 3-16.

LDCM Spacecraft
Trapped Protons
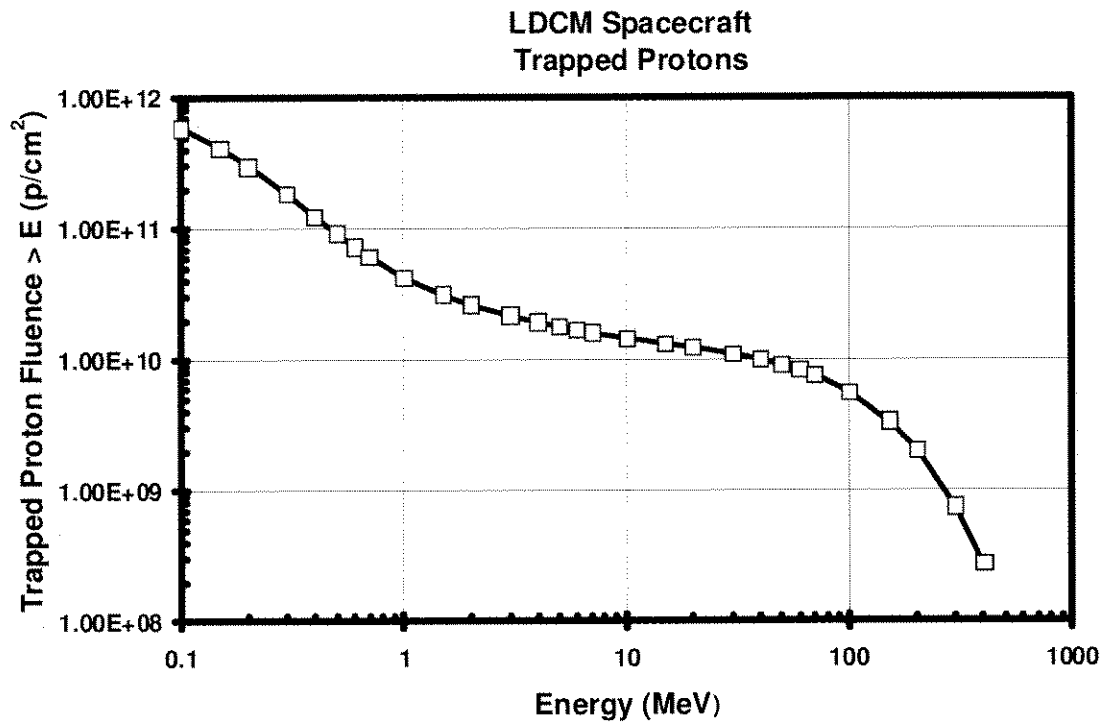
Figure 3-9. Surface Incident Integral Trapped Proton

**LDCM Spacecraft
Trapped Electrons**
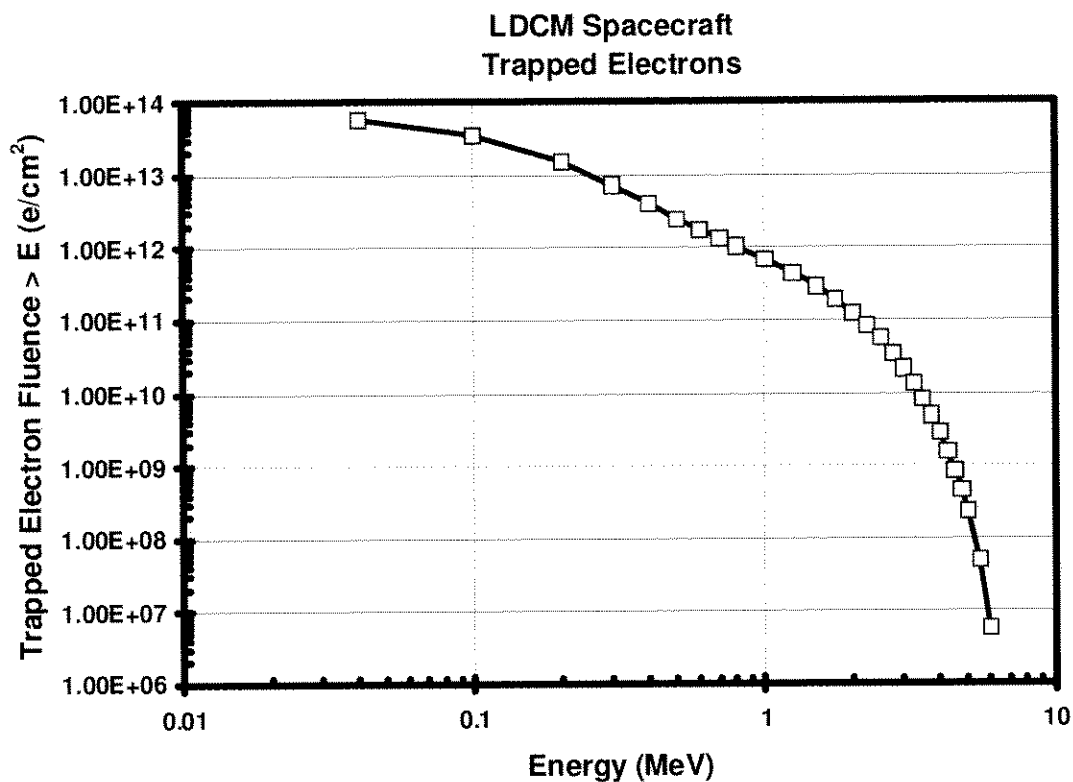
Figure 3-10. Surface Incident Integral Trapped Electron

LDCM Spacecraft
Solar Protons
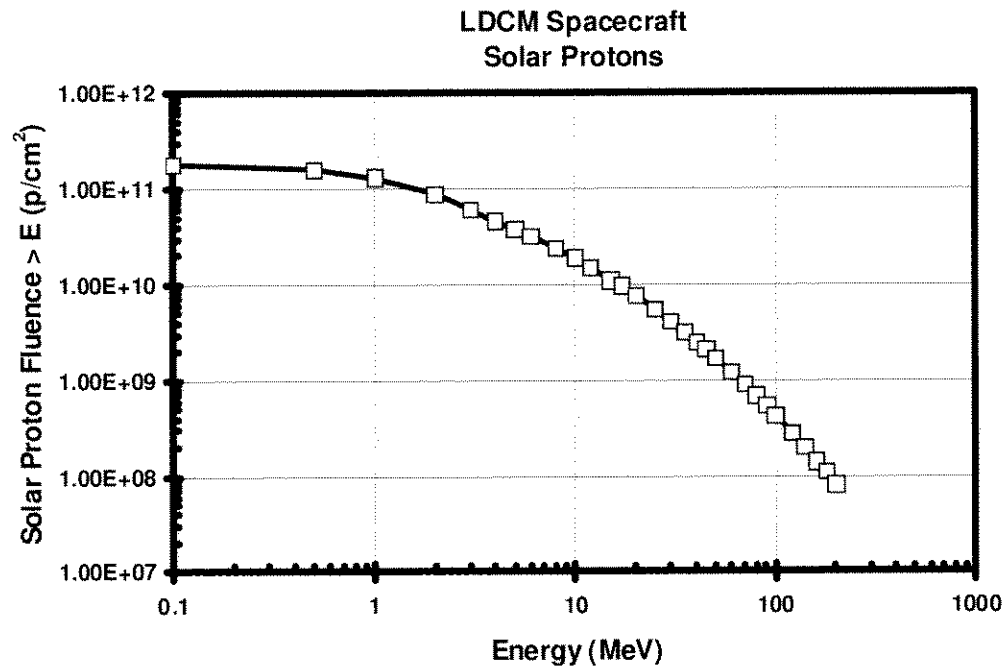
Figure 3-11. Surface Incident Integral Solar Proton

**LDCM Spacecraft
Dose-Depth Curves**
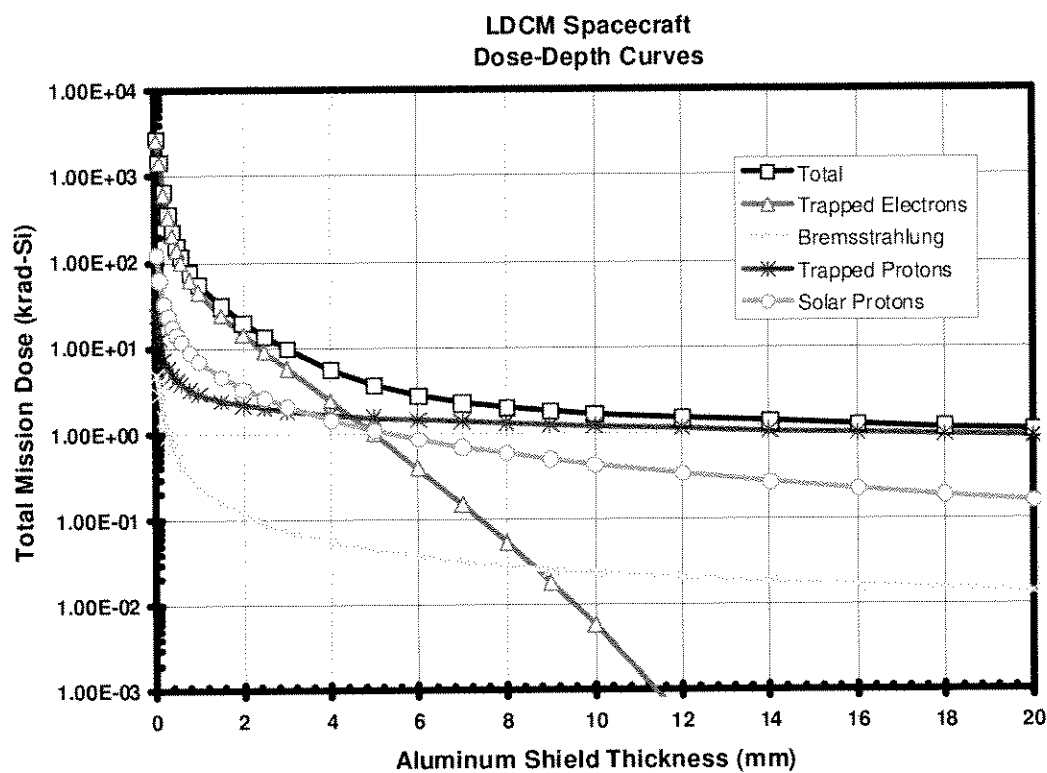
Figure 3-12. Total Ionizing Dose Curves for Dose at the Center of Solid Al Spheres.

CC-437   The Cooler shall utilize EEE Parts capable of meeting 20 krads (Si) Total Ionizing
Dose (TID).
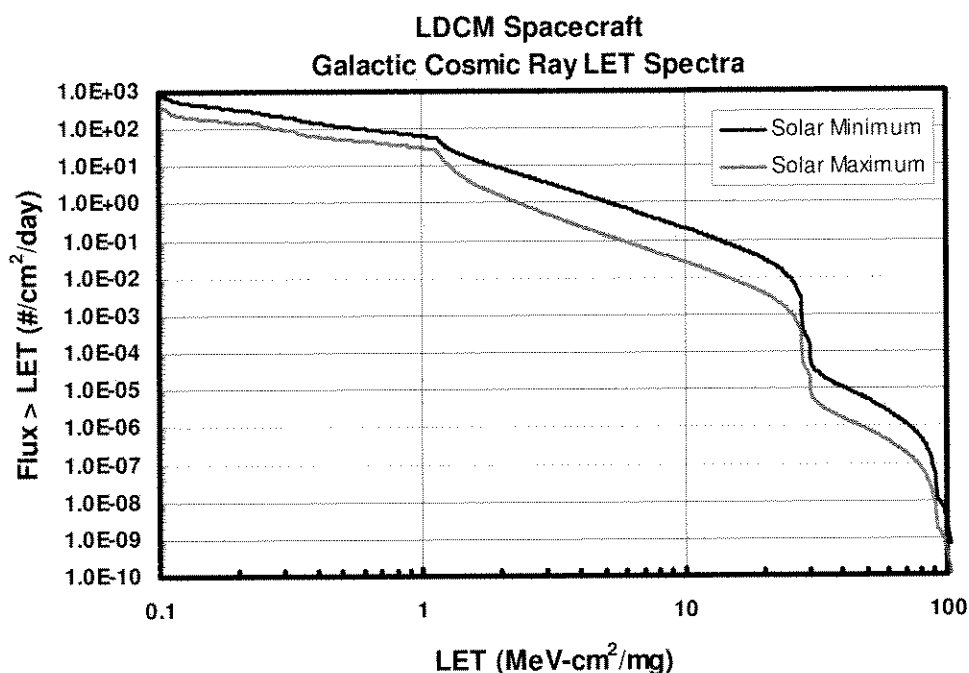
Figure 3-13. LET Spectra Galactic Cosmic Ray Ions Hydrogen through Uranium

Note: Figure 3-13 assumes 100 mils of Al shielding.
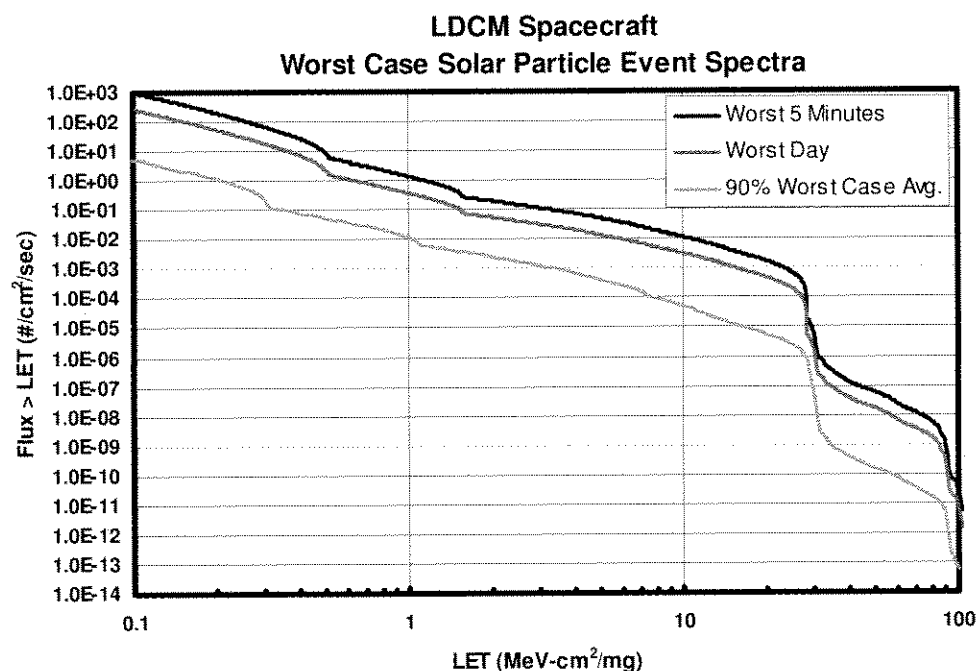
Figure 3-14. LET Spectra for Hydrogen through Uranium - 3 Worst Case Situations

Notes: In Figure 3-14, "Worst 5 Minutes" refers to the average over the peak 5 minutes of the 1989 event, "Worst Day" refers to the average over the worst day of the 1989 event, and "90% Worst Case Avg." refers to the average over the solar maximum period.

CC-444   The Cooler shall utilize EEE Parts capable of meeting a Linear Energy Transfer Threshold (LETth) of >37 MeV/mg/cm2 for soft errors from single events (SEU, Single Event Transients, etc).

CC-445   The Cooler shall utilize EEE Parts capable of meeting a LETth of >80 MeV/mg/cm2 for potential destructive events (SEL, SEB, SEGR,etc.).
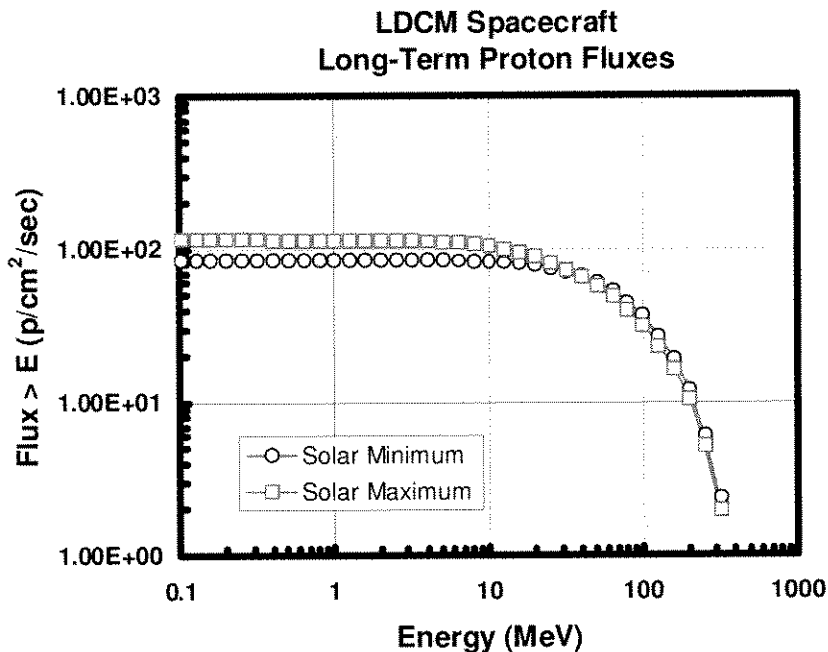
Figure 3-15. Long-Term Integral Proton Fluxes for SEE Evaluation

Notes: Figure 3-15 includes the trapped proton and solar proton fluxes behind 100 mils of aluminum shielding.

**LDCM Spacecraft
Worst Case Proton Fluxes**
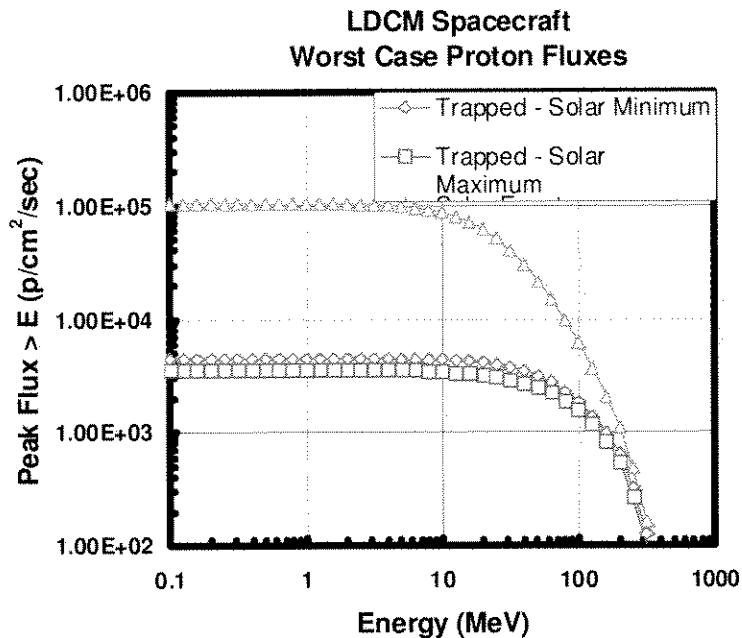
Figure 3-16. Worst Case Integral Proton Fluxes for SEE Evaluation.

Notes: Figure 3-16 includes the peak trapped proton fluxes averaged over a 1 minute interval during solar maximum and solar minimum. Also shown is the worst-case solar proton flux averaged over a 5 minute interval at the 90% confidence level. Calculations are done for 100 mils of aluminum shielding.

3.3.4 Structural & Mechanical Environment

CC-453   The total mass of the Cooler, including the TMU, CCE, and CCE-TMU harnesses shall be less than 30 kg.

CC-454   The total mass of the CCE shall be less than 10 kg.

CC-455   The Cooler shall use coordinates as described in the TIRS-Cooler ICD.

CC-456   The volume of the CCE shall be less than 30.48 cm x 30.48 cm x 30.48 cm.

CC-457   The volume of the TMU shall fit within the volume defined in Figure 3-17.
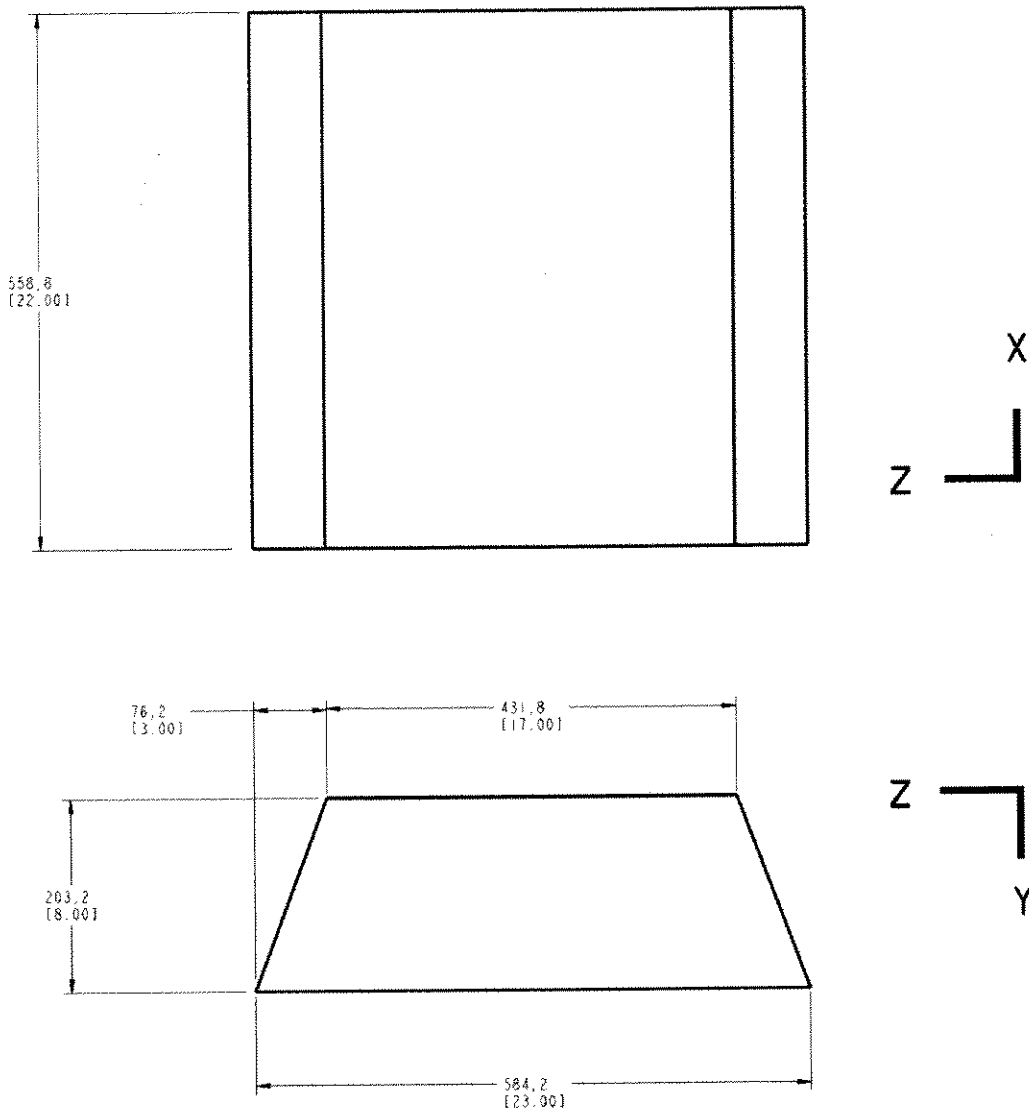
Figure 3-17. TMU Volume (mm, inches in [ ])

CC-460   The CCE to TMU harness length shall be documented in the TIRS-Cooler ICD.

CC-461   The CCE to TMU harness length shall be in the range from 2 to 4 meters.

CC-462   The mass of each Cooler component shall be measured to an accuracy of ±0.1 kg.

CC-463   The center of gravity of each Cooler component, referenced to its respective coordinate axes as documented in the TIRS-Cooler ICD shall be measured in three axes to ±0.003 meters.

Rationale: Measurement in most convenient axis is intended and used to check predictions. Mass balancing is not intended or expected.

CC-465   The Moments of Inertia (MOI) for each Cooler component, referenced to its
              respective coordinate axes as documented in the TIRS-Cooler ICD shall be
              predicted through analysis.

CC-466   The Cooler shall meet the performance requirements of this specification after
              exposure to interface temperatures during launch equal to the Flight Allowable
              Non-operating temperature range as documented in the TIRS-Cooler ICD.

CC-881   The Cooler shall be designed to satisfy the LV ascent pressure profile as specified
              in the Atlas 5, Model 401 vehicle Payload Planner's Guide at a maximum
              depressurization rate of -0.6 psi/sec.

CC-467   The Cooler shall meet the performance requirements of this specification after
              exposure to the base shake random vibration environment levels defined in Table
              3-2.

Table 3-2. Random Vibration Test Levels Components

Frequency	ASD Level (g^2/Hz) 22.7-kg (50-lb) or less	
(Hz)	Qualification	Acceptance
20	0.026	0.013
20-50	+6 dB/oct	+6 dB/oct
50-800	0.16	0.08
800-2000	-6 dB/oct	-6 dB/oct
2000	0.026	0.013
Overall	14.1 Grms	10.0 Grms

The acceleration spectral density level may be reduced for components weighing more than 22.7-kg (50 lb) according to:

	Weight in kg	Weight in lb	
dB reduction	$= 10 \log(W/22.7)$	$10 \log(W/50)$	
ASD(50-800 Hz)	$= 0.16 \cdot (22.7/W)$	$0.16 \cdot (50/W)$	for protoflight
ASD(50-800 Hz)	$= 0.08 \cdot (22.7/W)$	$0.08 \cdot (50/W)$	for acceptance

Where W = component weight.

The slopes shall be maintained at + and - 6dB/oct for components weighing up to 59-kg (130-lb). Above that weight, the slopes shall be adjusted to maintain an ASD level of 0.01 g^2/Hz at 20 and 2000 Hz.

For components weighing over 182-kg (400-lb), the test specification will be maintained at the level for 182-kg (400 pounds).
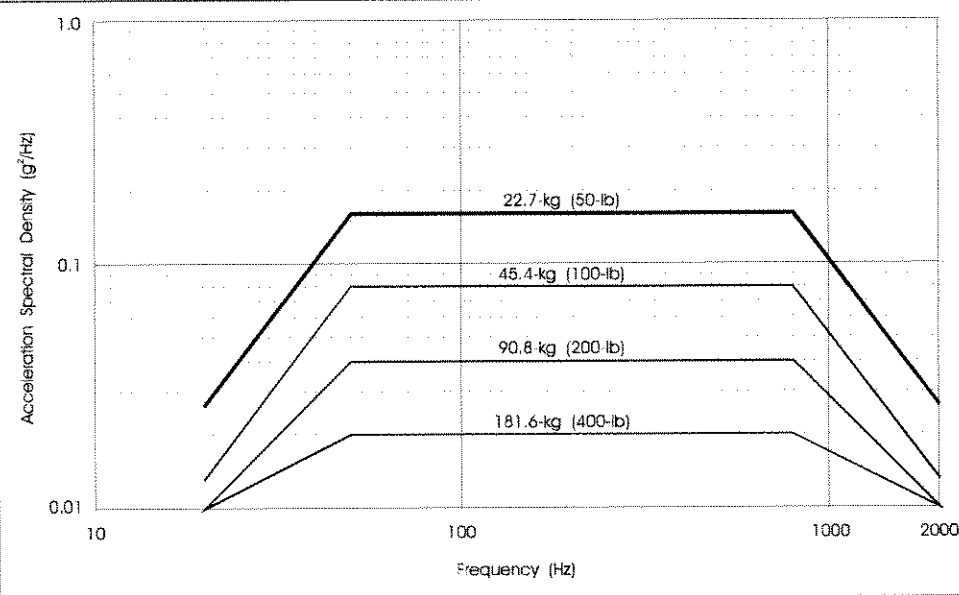
CC-511   The random vibration environment shall be applied in each of the three principal orthogonal axes.

CC-512   For Design and Qualification testing, the Qualification levels and durations shall be applied.

CC-513   If a flight-like qualification unit is not available, the first flight unit shall be subjected to protoflight levels and durations.

CC-514   The remaining flight units shall be subjected to flight acceptance levels and durations.

CC-515   Protoflight test duration shall be 1 minute for each of 3 mutually perpendicular axes.

CC-516   Acceptance test duration shall be 1 minute for each of 3 mutually perpendicular axes.

CC-517   Qualification test duration shall be 2 minutes for each of 3 mutually perpendicular axes.

CC-518   The Cooler shall meet the performance requirements of this specification after exposure to the quasi-static loads due to the low-frequency launch environment. These loads are given in the Mass Acceleration Curve (MAC) for components as shown in Figure 3-18, until a coupled loads analysis is completed. The design loads shown below will be updated based on the results of coupled loads analysis. The breakpoints for the MAC are given in Table 3-3. Linear interpolation may be used between break-points to determine limit load.
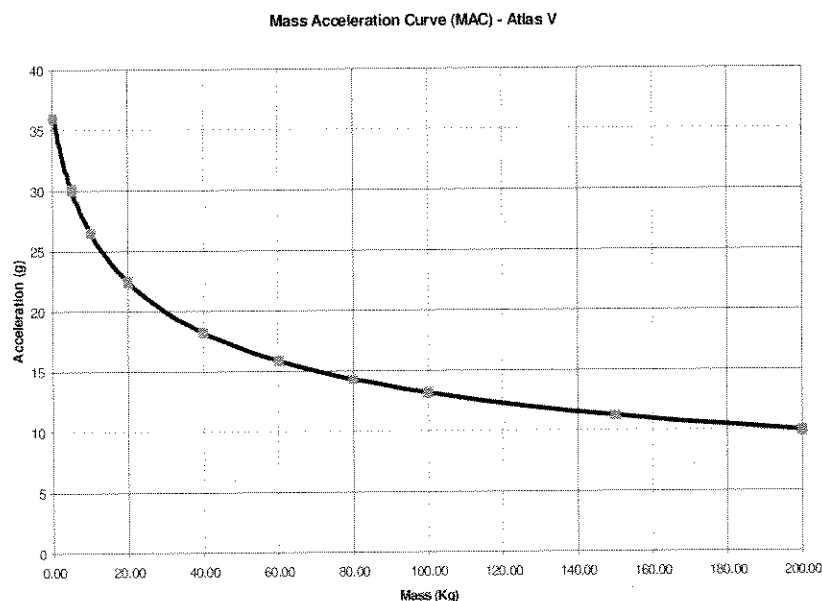
Figure 3-18. Component Mass Acceleration Curve (MAC)

Table 3-3. Component Design Loads (Break Points)

Component Mass (kg)	Limit Load (G, Any Direction)
1.0 or less	36.0
5	30.1
10	26.5
20	22.4
40	18.2
60	15.9
80	14.3
100	13.2
150	11.2
200 Kg. or Greater	10.0

CC-556   The Cooler components shall be designed to show positive margin for limit load using FS=1.25 for yield and FS=1.4 for ultimate.

CC-557   The Cooler components shall be tested to 1.25 times the limit load in 3 mutually perpendicular axes.

CC-558   The Cooler shall be designed to meet performance requirements following exposure to the externally induced shock environment specified in Table 3-4, as well as any self-induced shock. Notes: Testing of externally induced shock will be conducted at the SC level. The need for shock testing of Cooler assemblies will be evaluated on a case-by-case basis, depending on proximity to the shock source and sensitivity of the design to the shock environment (i.e. contains brittle or otherwise sensitive components such as relays).

Table 3-4. Shock Response Spectrum for Cooler Equipment

Assembly (location)	Frequency (Hz)	Max Flight Accel PK g
CCE (S/C Equipment Panels)	100	48
	602-8000	628
	10000	837
TMU	100	38
	684 - 8000	593
	10000	791

CC-576   Each separately mounted Cooler component configured for launch, including mounting brackets, shall have a fixed-base frequency greater than 100 Hz (i.e Cooler Powered Off).

3.3.5   Contamination Environment

Contamination control at the TIRS integration facilities will be described in the TIRS Contamination Control Plan (TIRS-SE-PLAN-0010).
The Cooler will be integrated with TIRS in a Class 10,000 per FED-STD-209E (Class 7 per ISO 14644-1) clean room environment and maintained in that environment as much as possible during the integration and test flow.
Note: This satisfies, as a minimum, the requirements described in the Federal Standard Airborne Particulate Cleanliness Classes in Cleanrooms and Clean Zones (FED-STD-209E).

CC-581   Cooler external (non-optical) surface contamination levels shall meet the values shown in Table 3-5, according to the Product Cleanliness Levels and Contamination Control Program, IEST-STD-CC1246D.

Table 3-5. Cooler External (Non-Optical) Surface Contamination Levels

Cooler External (Non-Optical) Surfaces	Particulate	Molecular
Delivery to TIRS	300	A
Launch	400	B
End of Cooldown (BOL)	415	C
EOL	450	G

CC-604   The Cooler shall be compatible with continuous operation in a Class 10,000 or better (ISO 14644-1 Class 7 or better) clean work area.

CC-605   The Cooler external surfaces shall be able to be cleaned without permanent degradation to the instrument. Where this is not possible or not recommended, (e.g., MLI) the contaminated components shall be replaced.

CC-606   Cooler exterior surfaces shall be readily cleanable with IPA using standard wipe techniques. The exterior surfaces shall be maintained at a surface particulate contamination Level 300 and surface molecular contamination Level A according to IEST-STD-CC1246D. Cooler assemblies that are sealed and vented with appropriate filters, such as electronic boxes, may exceed the Level 300 particulate requirement; however, the Level A nonvolatile residue (NVR) requirement must be met.

CC-607   Cooler materials shall be compatible with common cleaning agents.

CC-608   Upon delivery to TIRS, the outgassing rate for all Cooler components shall be less than $4.3 \times 10\text{-}12$ g/cm2-s.

CC-609   Cooler materials shall meet the minimum outgassing screening criteria as tested according to ASTM E595-93 or equivalent method. The materials shall have a

maximum total mass loss (TML) of 1.0% and a maximum collected volatile condensable material (CVCM) of less than 0.1%.

CC-610   The Cooler vendor shall identify all sources of contamination that can be emitted from the Cooler subsystem and document these sources for GSFC.

CC-611   Hardware shall undergo proper cleaning; including a vacuum bake-out to deplete any volatile material in the Cooler prior to on-orbit operations to meet required outgassing rates.

CC-612   The Cooler vendor shall be responsible for cleaning the Cooler.

3.4   OPERATIONAL REQUIREMENTS

CC-614   All real-time and closed-loop operations shall be handled internally by the Cooler.

CC-615   If the Cooler performs a self-diagnostic, the data shall be reported in a dedicated diagnostic telemetry stream.

CC-616   Cooler assemblies that contain microprocessors, micro-controllers, FPGAs, memory devices, and digital circuitry shall startup and shutdown into known logic states in an orderly internal sequence.

CC-617   The Cooler shall detect and respond to critical faults or operating conditions that have the risk of immediately damaging the Cooler or interfacing systems, and report the fault in a telemetry packet. Note: An example is automatic shut-off of compressors in the event that damaging temperatures or stroke/speed conditions are encountered.

CC-618   The Cooler shall be capable of overriding autonomous function and automatic safing, via ground command.

CC-619   In response to a Cooler fault protection trigger, the Cooler shall enter into a safe configuration that protects the instrument, while preserving the ability to monitor health and safety telemetry and respond to commands.

3.5   DESIGN AND CONSTRUCTION

3.5.1   Materials & Parts

CC-622   The Cooler shall comply with the TIRS Mission Assurance Implementation Plan (MAIP).

3.5.2   Connectors

CC-624   Separate connectors shall be used for each of the following: Primary and Redundant Power, RS-422, Test connection, Discrete Interfaces; and as applicable to the Cooler design.

CC-625   Connectors on a given surface shall be sized, oriented, keyed, or otherwise protected from an improper connection that would result in damage to equipment connected to either end of the harness.

CC-626   The Cooler shall use connectors selected from the GSFC Parts List (EEE-INST-002), or a GSFC-approved equivalent.

CC-627   The Cooler vendor shall not use blind mate electrical connectors.

CC-628   All connectors shall be accessible for mate/demate without removal of any adjacent objects (components, parts, bolts, etc.).

CC-629   When the Cooler is stand-alone, all connectors shall be accessible for mate/demate without the use of any custom tools.

CC-630   The Cooler connectors shall have a minimum of 0.0254 meter clearance provided around the outside of mated connector plugs.

CC-631   All connectors shall be clearly marked with a unique identifier.

CC-632   Connector savers shall be utilized on all flight connectors (both harness and bulkhead sides) prior to final connector/harness mate for flight with an exception for the EMI testing.

CC-633   All connectors, when not mated, shall have either protective covers installed, or shorting connectors installed depending upon the function of the connector.

CC-634   All connectors shall have a minimum of 10% spare pins.

APPENDIX A - ACRONYM LIST

Abbreviation/ Acronym	DEFINITION
ASD	Amplitude Spectral Density
ASTM	American Society for Testing and Materials
BOL	Beginning of Life
CBE	Current Best Estimate
CCA	Cooler Compressor Assembly
CCB	Configuration Control Board
CCE	Cooler Control Electronics
CDH	Command & Data Handler
CE	Conducted Emissions
CHA	Cold Head Assembly
CM	Configuration Management
CMN	Common Mode Noise
CMO	Configuration Management Office
CS	Conducted Susceptibility
CVCM	Collected Volatile Condensable Material
DC	Direct Current
EEE	Electrical, Electronic and Electromechanical
EGSE	Electronic Ground Support Equipment
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EOL	End of Life
EOP	EOL Operating Point
ETAS	Environmental Test Authorization and Summary Form
FM	Flight Model
FPA	Focal Plane Array
FPE	Focal Plane Electronics
FPGA	Field Programmable Gate Array
FSW	Flight Software
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center

HSDB	High Speed Data Bus
ICD	Interface Control Document
ICD	Interface Requirements Control Document
ID	Identification
IEEE	Institute of Electrical and Electronics Engineers
IIRD	Instrument Interface Requirements Document
IT, I&T	Integration and Test
LDCM	Landsat Data Continuity Mission
LETth	Linear Energy Transfer Thershold
LEVR	LDCM Environmental Verification Requirements
LV	Launch Vehicle
MAC	Mass Acceleration Curve
MAIP	Mission Assurance Implementation Plan
MEB	Main Electronics Box
MIL	Military
MLI	Multi-Layer Insulation
MOI	Moment of Inertia
MSFC	Marshall Space Flight Center
MSS	Maximum Steady State
NASA	National Aeronautics and Space Administration
NVR	Non-Volatile Residue
RD	Requirements Document
RE	Radiated Emissions
RS	Radiated Susceptibility
RS	Recommended Standard
SC,S/C	Spacecraft
SCA	Sensor Chip Array
SCTR	Special Calibration Test Requirements
SE	Systems Engineering
SEB	Single-Event Burnout
SEE	Single-Event Effects
SEGR	Single-Event Gate Rupture
SEL	Single Event Latchup
SEU	Single Event Upset

SFT	System Functional Test
SSM	Scene Select Mechanism
STD	Standard
TID	Total Ionizing Dose
TIRS	Thermal Infrared Sensor
TLA	Thermal-Link Assembly
TML	Total Mass Loss
TMU	Thermal Mechanical Unit
USGS	US Geological Survey
VAFB	Vandenberg Air Force Base
VCM	Volatile Condensable Material